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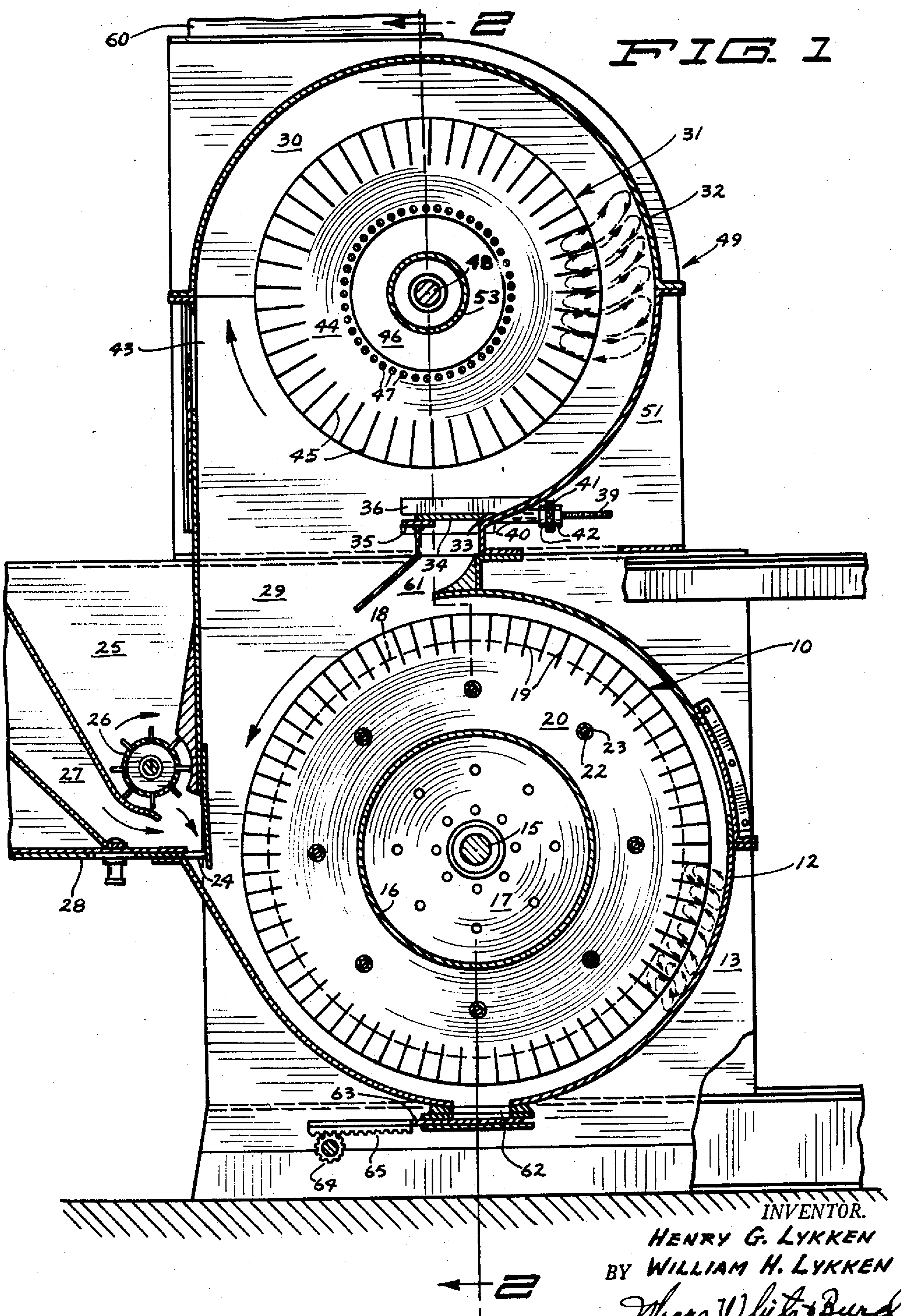
SYNERGISTIC FLUID ENERGY REDUCING AND CLASSIFYING UNIT

Filed Oct. 15, 1956 2 Sheets-Sheet 1



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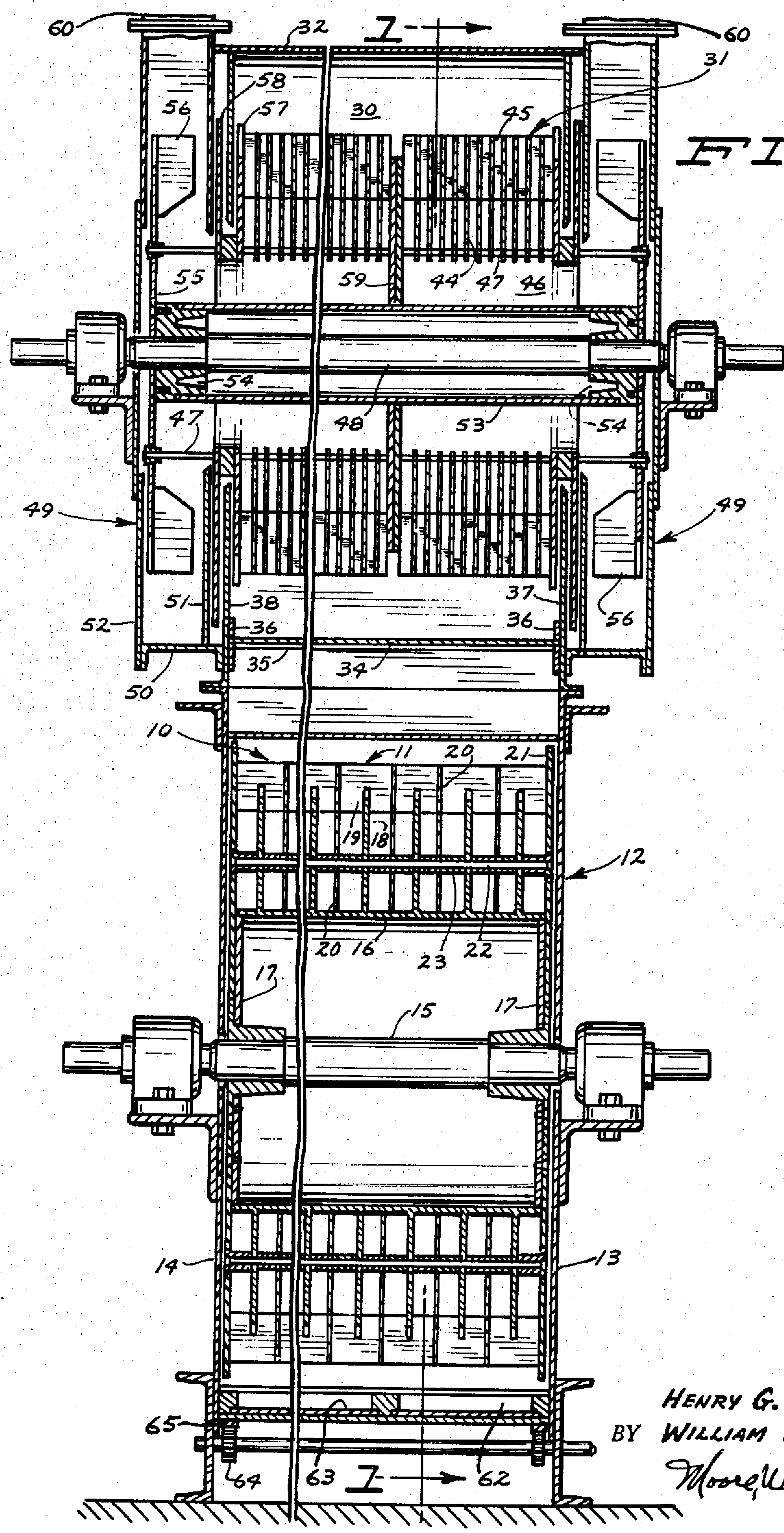

FIG. 2

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SYNERGISTIC FLUID ENERGY REDUCING AND CLASSIFYING UNIT

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11 Claims. (Cl. 241—52)

This invention relates to the reduction and classification of dry solid materials. More particularly this invention relates to an open rotor fluid energy mill with centripetal extraction classification for the reduction of dry material to any specified particle size and finer in the subsieve range.

The reduction of any material on a commercial scale to specific particle size and finer in the subsieve range is an art. It is an art which requires its own essential techniques, processes, methods and means. It is not an art which can be practiced merely by the provision of a mill plus a classifier. More than this is required. Of necessity, there is required a complex and completely integrated unit of many interdependent elements, parts and processes, which, because of their interdependence can only act as a unit and must be so considered.

It is a well known and universally accepted fact, that in any grinding operation, the accumulation of fines, particularly subsieve material, in the mill load has a retarding and cushioning effect. Ten percent of fines in the mill load will reduce the mill capacity 50% or more. This reduction in mill capacity increases at an accelerated rate as the fines increase. The rate will vary with the character of the material being reduced but doubles and redoubles in effect as the desired cut size becomes finer, until further reduction becomes negligible.

So, in milling practice, with any kind of mill, the fines must be continuously removed from the mill load. Milling efficiency depends on the completeness of this removal, since no fines (that is, material of the wanted particle size and finer) in the mill load is the optimum condition for maximum reduction.

En masse, finely divided material acts like a fluid, made up as it is of particles with little body and negligible mass. It yields to impact and pressure with negligible internal friction and particle-on-particle abrasion. It acts more like a fluidal lubricant. Any material, after reaching a certain fineness seems to evade further reduction by normal methods and means of grinding. Maximum efficiency in milling requires not only efficient reduction means, but interacting classifying means to assist the reducing means by continuously and instantaneously removing the wanted particle size and finer from the mill load and continuously returning the oversize for further reduction. At the same time, in order to achieve a greater rate of reduction and a greater degree of fineness it is necessary that the material particles be highly dispersed in air, uniformly and independently.

The invention is illustrated by the drawings in which the same numerals refer to corresponding parts and in which:

Figure 1 is an end elevation, in section, of the synergistic fluid energy reducing and classifying unit of this invention, the section being taken along the line 1—1 of Figure 2 and in the direction of the arrows; and

Figure 2 is a side elevation, in section, taken on the line 2—2 of Figure 1 and in the direction of the arrows.

The reducing element of the synergistic unit comprises a lower horizontal axis peripheral inlet and peripheral discharge closed end rotor **10**, preferably including an assembly of like closed end rotor units **11**.

The rotor is contained in a reducing chamber enclosed by a generally cylindrical housing **12** around about three-fourths of the periphery of the rotor. Housing **12** is held between two end plates **13** and **14** which extend to a base or floor and are affixed by floor flanges.

A suitable bearing structure adequately sized to carry the reducing rotor is mounted at each end of the housing outside of the end plates. Upon these bearings there is mounted a shaft **15** which carries the reducing rotor. Shaft **15** is driven by any suitable drive means, not shown. The shaft is enlarged and reinforced through part of its length by a tube **16** supported by annular rings **17** welded or otherwise secured to sleeves keyed to the shaft. The shaft, tube and annular rings form a rigid unitary structure upon which the reducing rotor units **11** are mounted.

The closed end rotor units **11** are comprised of a slotted annular disk **18** perpendicular to the shaft and carrying a plurality of flat radial blades **19** around its periphery. Radial blades **19** are positioned perpendicular to the slotted disk and each unit is enclosed between a pair of disks **20** having diameters reaching to the periphery of blades **19**. A series of rotor units is mounted on the rotor between a pair of rotor end disks **21** mounted on each end of tube **16** and secured to the annular rings. The disks **18** and **20** are supported by a plurality of bolts **22** extending between end disks **18** and surrounding tube **16**. The disks are held spaced apart by spacers **23**.

The reducing rotor **10** develops a relatively high axial vacuum due to a high centrifugal discharge on the forward or leading face of each blade **19** and to the velocity of recession at the back of each blade. This vacuum drags air and material into the rotor at the back of each blade with a velocity considerably higher than the peripheral velocity of the rotor itself and discharges the air and material on the forward face of the next or trailing blade. There is set up a high velocity in-and-out flow between each pair of blades which induces an intense fluid energy vortex between the blades, and, at the same time, corresponding unit vorticose flows in the fluidal material circulating around the rotor.

The reducing rotor **10** is mounted in the housing **12** with a running clearance of two inches, more or less (that is, between about 1 and 3 inches depending upon material, velocity, volume of air, etc.), between the periphery of the rotor and housing wall around about three-fourths of the periphery of the rotor. The mill load is maintained in a highly fluidal condition, such as, for example, one part solids by volume to about 6 to 12 parts of air, and, preferably, one part solids by volume to about 8 to 10 parts of air.

The fluidal mill load circulates at moderate velocity with the rotor and is continuously and repeatedly sucked into and discharged by the motor. Particles which are too large to enter into the rotor are nibbled down by blade impact until they are of a size which does enter. Then they are progressively reduced by repeated blade impact each time they enter and/or discharge.

The primary reduction of the dry solid material is by continuous and repeated rotor blade impact or clipping action on the individual dispersed particles. As each particle reduces in mass it enters the rotor further and further and is subjected repeatedly to its intra-blade high intensity fluid energy vortex. The reduction in the vortex is the result primarly of abrasion of spinning particles upon each other.

The action of the reducing rotor is conditioned by its blade spacing, radial depth of blade and its peripheral velocity, all of which may vary with the type and character of the material to be reduced. For material requiring a shearing action cutting edge rotor blades are used. The mill housing is split so the top can be lifted off and the rotor lifted out and turned end for end periodically to provide a self-sharpening blade wear.

The mill feed enters the reducing rotor chamber tangentially at inlet 24 below the axis of the rotor along its full length in a regulated amount from an elongated feed hopper 25 to maintain a desired bulk or weight of material in the circulating mill load. The feed is preferably regulated by an interlock between the motor operating the metering closure 26 of the feeder and the reducing rotor motor so as to regulate the feeder motor to maintain a uniform mill load. The mill load can be set at any desired fluidity or material to air ratio in the circulating flow. Air is admitted through air duct 27 with the material feed, so regulated, as by a slide damper 28, that upon every revolution of the rotor all of the wanted particle size and finer is continuously carried out of the circulating load with a minimum of oversize.

The lower reducing rotor acts as a powerful peripheral fan. It has a peripheral inlet with a substantial suction into which the air and material is fed, and a high velocity peripheral discharge at the top. This provides for several independently controlled, but interacting, synergistic air flows in the reducing and classifying unit as a whole.

The fixed air content in the reducing chamber is circulated by and around the lower reducing rotor continuously. The air drawn into the reducing chamber by the rotor is discharged into an open chamber 29 at the top of the rotor with high velocity pressure, thence up into the classifying chamber 30, over the upper classifying rotor 31 and into a circulating flow around it. Part of this air flow follows the peripheral wall 32 of the classifying chamber down through a skimmer gate 33 for the return of oversize to the reducing rotor where it receives an additional velocity impulse and suction drag by the reducing rotor and recirculates.

This circulation is controlled by the swimmer gate 33 which comprises the space between classifier chamber wall 32 and the beveled edge of an elongated plate 34. Plate 34 slides between a horizontal support 35 which extends the length of chamber 30 spaced apart from the back wall and between hold down plates 36 on the end walls 37 and 38 at the opposite ends of the chamber. The beveled edge of plate 34 has at least two rods 39 projecting from it and passing out through tubes 40 on the outside of the chamber wall. At least one of rods 39 is preferably screw threaded and provided with a threaded thumb wheel 41 (between two fixed collars 42) by which plate 34 may be moved and the width of the skimmer gate may be adjusted.

The air from the reducing chamber circulating around the classifier rotor 31 enters the rotor radially and goes out axially. It is, however, only part of the air required for classification, usually the lesser part. Supplemental air is admitted through an adjustable opening 43 into the classifier duct or open chamber 29 between the reducing and classifying chambers to mingle with the air flow from the reducing chamber. A slide damper permits ready adjustment of this supplemental air flow.

The upper classifying rotor 31 is an assembly of spaced slotted annular disks 44 and spaced radial blades 45 intersecting the disks. The inner edges of spaced disks 44 define an annular axial outlet duct 46 from the rotor. The disks 44 are supported at the periphery of duct 46 by a series of closely spaced rods or bolts 47 which form inlet-outlet ports having a uniform air resistance.

The upper rotor 31 is contained in a classifying chamber 30 enclosed by a generally cylindrical housing 32 around about three-fourths of the periphery of the rotor. Housing 32 is held between two end plates 37 and 38 which rest upon the tops of end plates 13 and 14, respectively, of the reducing chamber housing. End plates 37 and 38 each have an annular opening through which a central rotor shaft 48 passes and through which the axial duct 46 of rotor 31 communicates with discharge means.

Spaced apart from the classifying chamber housing 32 at each end is a fan housing 49 including a cylindrical wall 50 held between an inner end wall 51 having an annular opening corresponding to that in classifier end walls 37 and 38, and an outer end wall 52. A suitable bearing structure adequately sized to carry the classifier rotor and fans is mounted at opposite ends of the fan housings outside of the end plates. Shaft 48 is mounted on these bearings. It may be driven by an suitable drive means. The shaft 48 is enlarged and reinforced through part of its length by a tube 53 supported by sleeves 54 keyed to the shaft. Sleeves 54 also support annular fan disks 55 upon which fan blades 56 are mounted.

Rods 47 extend between fan plates 54. The portion of the rotor within housing 32 is supported between end disks 57. Further end disks 58 are supported by rods 47 in the spaces between the end walls 37 and 38 of the classifier chamber housing and the inner end walls 51 of the fan housings to suppress any air flows which might otherwise be induced around the ends of the rotor.

Depending upon the length of the synergistic reducing and clasisfying unit either one or two fan units may be used. Where two fans are used, as illustrated, a further disk 59 is mounted on tube 53 of the rotor to divide axial duct 46 into two parts and to direct air flows to one fan or the other.

The entire air flow through the classifier rotor (as distinguished from flows within the classifying rotor and chamber) is a function of an independently driven exhaust fan (not shown) associated with a standard collector system and having ample static capacity. The classifier rotor discharges into the fan housing 49, which acts as an outlet box. The fan housing is provided with a discharge duct 60 by which it is connected to the collector system. The centrifugal fan unit in the outlet box is primarily an axial suction or flow equalizer having some incidental fan effect. In the suction line between the outlet box and exhaust fan (not shown) is a precise air flow regulating device. Variation in air flow regulates the particle size in the product.

The bottom wall of the reducing chamber is provided with an opening 62 or a plurality of openings along the length of the chamber. This opening is provided with a slide damper 63 or similar means for progressively withdrawing bits of sand, stone, grit, metal and like extraneous heavy material from the mill load. Initially, this grit trap will become filled with the material to be reduced, but as grit and like material is introduced into the reducing chamber along with the feed, it will, because of its greater density, drop to the bottom of the trap.

As shown here, the outer edge of damper 63 is supported by a splined shaft or a shaft bearing spur gears 64 whose teeth mesh with the teeth of racks 65 on the lower surface of the slide damper. The shaft bearing the spur gears is suitably provided with a lever or crane handle for adjusting the slide, or preferably is provided with a variable speed drive synchronized with the feeder drive to discharge a predetermined fixed percentage of the feed through the grit trap.

As already noted, the classifier rotor 31 is arranged to rotate at a regulatable peripheral velocity in the direction of the air flow around it. It is a peripheral inlet, axial outlet centripetal extraction rotor arranged to operate on a progressive particle size selection principle. This rotor has many and diverse functions.

In fine particle classification the material must be thoroughly aerated. Each and every particle must be enclosed in a film of air and be individually and uniformly dispersed in the carrier air. This is a factor which is often overlooked but is absolutely essential to precise classification. In the synergistic apparatus of this invention aeration of the particles is a function of the reducing rotor and the material enters the classifying chamber thoroughly aerated.

Additional air must then be added to provide the proper dilution. The finer the material the more air is called for. This air is admitted in regulated amounts through air inlet **43**. The material must be uniformly distributed in the air, and equally important, it must be maintained uniformly distributed as it circulates around the classifier rotor. These are both functions of that rotor.

The classifier rotor has the same in-and-out flow between each pair of blades, the same intra-blade vortex action and vorticose air flow in the circulating air flow around the rotor as the reducing rotor has, and more so. It maintains the perfect mixture of air and material.

The classifier rotor is rotated at a peripheral velocity to provide the desired centrifugal throw-out effect or "*g*" in the circulating flow and within the rotor itself, proportional to particle size and mass. This is a third function of the classifying rotor. By virtue of its partial axial vacuum and intra-blade vortex action, it continuously withdraws and expels the circulating flow of material, uniformly distributed in the air. This is done selectively with the particles of smallest size and least mass entering farthest into the rotor, particles of somewhat larger size and greater mass entering somewhat less far into the rotor, etc. That is, the fines enter the rotor to a radial depth inversely proportional to their mass. This is a fourth function of the classifying rotor and is independent of any air drawn into the rotor. The circulating material continuously and repeatedly enters the rotor and discharges. Most of the oversize circulating on the classifier chamber wall is continuously skimmed off at gate **33** and returned to the reducing chamber through duct **61**. The oversize and the circulating air flow is discharged tangentially into the peripheral flow of the reducing rotor on the principle of a suction ejector as a means of maintaining this circulating flow.

If no air is drawn through the rotor, no material gets through. A trace of air allows only a colloidal smoke through. As the air flow through the rotor increases the particle size increases proportionally. Precision air flow control provides precision particle size control, provided the other functions of the classifying rotor are present.

As an example, if the desired particle size is 7 microns and finer no larger particles should be permitted to pass through the classifier rotor. The unit is set by regulation of the air flow through the classifier to pass 7 micron material and finer, but with a wide margin of safety. It is set so as to pass only a small percentage of the particles as large as 7 microns in the material that continuously and repeatedly comes to the cut-off line within the classifier rotor. The particles of desired size and finer may be presented to the cut-off line as often as a hundred times a second. It is only necessary to pick off and withdraw a few of these particles on each circuit into the rotor. Eventually all come in with no chance for oversize to get in. Particles finer than 7 microns are withdrawn on their first pass into the classifier rotor.

The accomplishment of this desired precise classification on a commercial scale, of course, requires ample volumetric capacity, diameter and length of rotor. It calls for a multiplicity of annular disk channels proportional to the capacity wanted. Precise classification can be achieved in the particle range down to all minus one micron.

The classifying rotor can be operated at a relatively low rotative velocity and with relatively low air flow velocity and with maximum precision of flow control, particle distribution and particle size distribution in the air flow. The screen-like static resistance ports formed between the annular disks **44** and rods **47** at the periphery of axial duct **46** are an added assurance of precision operation.

The principle of classification used with the unit of this invention involves subjecting the reduced material (in a highly fluidal suspension and uniform individual particle dispersion in a gas, such as air) to two opposing forces: first, the drag of the suspending gas drawn centripetally into a peripheral inlet, axial outlet centripetal extraction rotor (Stoke's law); the other, centrifugal force on each individual particle, which is proportional to the mass of the particle.

The centrifugal force can be adjusted to any desired value by varying the speed of the rotor. For operation, it is preferably set for a constant value, such as from about 1000 to 2000 *g* at the periphery of the rotor, varying somewhat with the specific gravity of the material and particle size to be extracted. As an example, a rotor 30 inches in diameter rotated at 1530 r.p.m. has a centrifugal force of 1000 *g* at its periphery. Particle size control then becomes merely a matter of precise regulation of air volume through the classifier.

The method of reducing and classifying dry solid material according to this invention may be illustrated as follows: A controlled supply of dry solid material to be reduced is fed tangentially downwardly into the reducing housing in which the reducing rotor is rotating. The reducing rotor acts as a fan which induces the feed and air into the housing, circulates it around the rotor while subjecting the material to high velocity impact and fluidal vortex action, and induces a circulating flow of air in the classifying chamber for carrying the fines up and out of the reducing area and for returning rejected oversize material to the reducing rotor for further reduction. The reduced material is carried upwardly in a highly aerated suspension and introduced tangentially into the classifier housing in which the classifying rotor is rotating. The classifying rotor acts to induce air in through the auxiliary air inlet, to further dilute the gaseous suspension of reduced particles, to uniformly distribute the particles in the suspension and to maintain the uniform distribution while circulating the stream of particles around the rotor, subjecting the particles to controlled centrifugal stresses and to selectively segregate the circulating particles. The desired fines are withdrawn axially by suction through the classifying rotor to a collector system and the rejected oversize particles are skimmed off the classifier housing wall and returned in the circulating air stream to the reducing rotor. The fan action of the reducing rotor creates a suction which withdraws the oversize and returns it for further reduction.

It will be seen that the assembly as a whole is simple in design, rugged in construction, low in power and maintenance costs, extremely accessible, elemental and almost automatic in operation, with precision performance.

It is apparent that many modifications and variations of this invention as hereinbefore set forth may be made without departing from the spirit and scope thereof. The specific embodiments described are given by way of example only and the invention is limited only by the terms of the appended claims.

We claim:

1. A synergistic fluid energy reducing and classifying unit comprising reducing means including a peripheral inlet, peripheral discharge, closed end reducing rotor mounted to rotate in a horizontal cylindrical housing, said rotor including a shaft, a plurality of spaced apart discs mounted perpendicular to said shaft and a plurality of intersecting radial blades parallel to the shaft and perpendicular to said discs carried at the periphery of said discs, said discs dividing the rotor into a plurality of separate rotor units, the running clearance between the periphery of said rotor and the cylindrical wall of said housing being of the order of from about 1 to 3 inches to provide for a highly fluidal mill load of from about one part solids to about 6 to 12 parts air by volume, a tangential inlet to said housing for material to be reduced and air, said inlet being disposed along the length of said housing and at about the level of the axis of the

reducing rotor, means associated with said inlet for regulating the rate of material feed and air flow, a tangential reduced material and air outlet above said reducing rotor; classifying means integrated with the reducing means and superimposed upon it, said means comprising a peripheral inlet, axial outlet, centripetal extraction classifying rotor mounted to rotate in a horizontal cylindrical housing, a tangential reduced material and air inlet to said housing connected with the reduced material and air outlet of said reducing means, and a tangential return duct from said housing to return oversize material to the reducing rotor.

2. A reducing and classifying unit according to claim 1 further characterized in that an axial exhaust chamber is associated with the classifying means.

3. A reducing and classifying unit according to claim 1 further characterized in that the tangential reduced material inlet of the classifier inlet is provided with an auxiliary air inlet and air flow control means.

4. A reducing and classifying unit according to claim 1 further characterized in that an adjustably movable skimmer gate is provided in said tangential return duct to regulate the desired volume of flow circulating around the classifying rotor.

5. A reducing and classifying unit according to claim 1 further characterized in that said classifying rotor is comprised of an assembly of spaced annular disks and spaced intersecting radial blades forming radial ducts opening into an axial outlet duct, said axial duct having a peripheral wall of spaced rods defining inlet ports from the radial ducts.

6. A classifying unit comprising a peripheral inlet, axial outlet, centripetal extraction classifying rotor made up of an assembly of spaced annular disks and spaced intersecting radial blades forming radial ducts opening into an axial outlet duct, said axial duct having a peripheral wall of spaced rods defining inlet ports from the radial ducts, said rotor mounted to rotate in a horizontal cylindrical housing of substantially larger diameter, a tangential inlet duct at the bottom of said housing for reduced air borne material, a tangential discharge duct from said housing adjacent to said inlet duct for rejection of oversize particles, both of said tangential ducts being the full length of the housing, and an axial exhaust chamber at at least one end of said axial duct.

7. A classifying unit according to claim 6 further characterized in that said tangential inlet duct is provided with an auxiliary air inlet having an inlet air control.

8. A classifying unit according to claim 6 further characterized in that said tangential discharge duct is provided with an adjustably movable skimmer gate to regulate the desired volume of flow circulating around the classifying rotor, said skimmer gate being the full length of the housing.

9. A synergistic fluid energy reducing and classifying unit comprising reducing means including a peripheral inlet, peripheral discharge, closed end reducing rotor mounted to rotate in a horizontal cylindrical housing, the running clearance between the periphery of said rotor and the cylindrical wall of the housing being of the order of from about 1 to 3 inches to provide a highly fluidal mill load of from about one part solids to about 6 to 12 parts air by volume, a tangential inlet to said housing for material to be reduced and air, said inlet being disposed along the length of the housing and at about the level of the axis of the reducing rotor, means associated with said inlet for regulating the rate of material feed and air flow, a tangential reduced material and air outlet above said reducing rotor; classifying means integrated with the reducing means and superimposed upon it said means comprising a peripheral inlet, axial outlet, centripetal extraction classifying rotor mounted to rotate in a horizontal cylindrical classifying rotor housing, said rotor being made up of an assembly of spaced annular disks and spaced intersecting radial blades forming radial ducts opening into an axial outlet duct, said axial outlet duct having a peripheral wall of spaced rods defining inlet ports from the radial ducts, a tangential reduced material and air inlet to said classifying rotor housing connected with the reduced material and air outlet of said reducing means, an auxiliary air inlet in said tangential inlet to the classifying rotor housing, air flow control means for said auxiliary inlet, a tangential return duct from said classifying rotor housing to return oversize material to the reducing rotor, an adjustably movable skimmer gate in said return duct to regulate the desired volume of flow circulating around the classifying rotor and at least one axial exhaust chamber associated with the classifying means to connect the axial outlet of the classifying rotor with an exhaust fan, air flow regulating means and a material collector system.

10. A classifying unit comprising a peripheral inlet, axial outlet centripetal extraction classifying rotor made up of an assembly of spaced annular disks and spaced intersecting radial blades forming radial ducts opening into an axial outlet duct, said axial duct having a peripheral wall of spaced rods defining inlet ports from the radial ducts, said rotor mounted to rotate in a horizontal cylindrical housing of substantially larger diameter, a tangential inlet duct at the bottom of said housing for reduced air borne material, an auxiliary air inlet in said tangential material inlet duct, air flow control means for said inlet, a tangential discharge duct from said housing adjacent to said inlet duct for rejection of oversize particles, both of said tangential ducts being the full length of the housing, an adjustably movable skimmer gate the full length of the housing to regulate the desired volume of flow circulating around the classifying rotor and at least one axial exhaust chamber in communication with the axial outlet of the classifying rotor.

11. A synergistic reducing and classifying system comprising a horizontal generally cylindrical reducing housing; a horizontal generally cylindrical classifying housing superimposed upon the reducing housing; an interconnecting tangential outlet duct from said reducing housing and tangential inlet duct to said classifying housing between said housings; an air inlet in said inlet duct; an interconnecting tangential outlet duct from said classifying housing and tangential inlet duct to said reducing housing between said housings; a tangential material and air inlet to said reducing housing and an axial material and air discharge from said classifying housing; closed end rotor means mounted to rotate on a horizontal axis in said reducing housing to act as a peripheral inlet and peripheral discharge fan to induce air and material into the reducing chamber, to circulate air and material about itself and induce high velocity impact and a fluidal vortex action, and to induce a circulating flow of air up through the tangential outlet duct of the reducing housing and the tangential inlet of the classifying housing, around the outer periphery of the classifying housing and down through the tangential outlet duct of the classifying housing and the tangential inlet of the reducing housing; peripheral inlet, axial outlet, centripetal extraction rotor means mounted to rotate on a horizontal axis in said classifying housing to induce supplemental air from the air inlet in the tangential inlet to the classifying housing, to dilute and maintain a uniform suspension of reduced particles in air, to maintain the uniform distribution of particles while circulating the suspension around the rotor means, to subject the particles in the suspension to controlled centrifugal stresses and to selectively segregate the circulating particles for withdrawal of the desired fines.

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CERTIFICATE OF CORRECTION

Patent No. 2,953,307 September 20, 1960

Henry G. Lykken et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 3, line 38, for "swimmer" read -- skimmer --; column 4, line 11, for "an" read -- any --.

Signed and sealed this 11th day of April 1961.

(SEAL)
Attest:
ERNEST W. SWIDER

Attesting Officer

ARTHUR W. CROCKER
Acting Commissioner of Patents